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(71) Applicant *(for all designated States except US)*: **STANADYNE AUTOMOTIVE CORP.** [US/US]; 92 Deerfield Road, Windsor, CT 06095 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **DJORDJEVIC, Ilija** [US/US]; 159 Kimberly Road, East Granby, CT 06026 (US).

(74) Agents: **RISTAS, L., James** et al.; Alix, Yale & Ristas, LLP, 750 Main Street, Hartford, CT 06103 (US).

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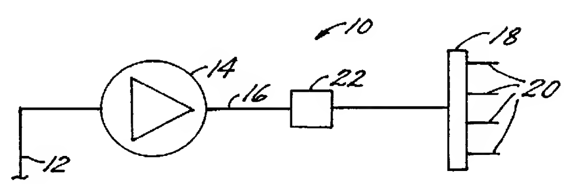
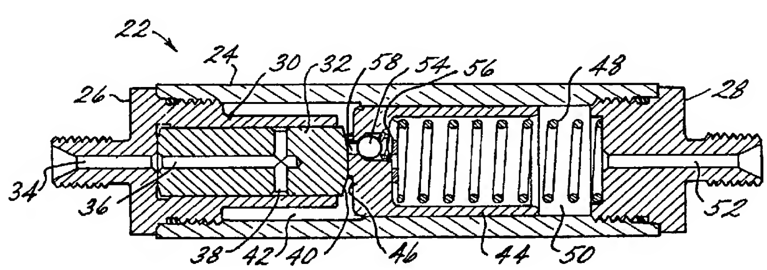
[Continued on next page]

(54) Title: FLOW INTENSIFIER FOR COLD STARTING GASOLINE DIRECT INJECTION ENGINE





(57) Abstract: In a common rail gasoline fuel injection system having a high pressure fuel supply pump (14) in which fuel is pressurized in a pumping chamber and delivered through a high pressure passage (16) to the common rail (18), the improvement comprising a flow volume intensifier (22) situated in the high pressure passage (16). Preferably the intensifier has a cranking configuration in which a primary piston (32) of relatively low effective cross sectional area on which only the primary pressure of the pumping chamber is imposed, and a secondary piston (44) contacting the primary piston (32) and having a relatively large effective cross sectional area on which only the common rail pressure is imposed, whereby when the primary piston (32) is displaced a primary volume toward the secondary piston (44) by the primary pressure from the pumping chamber, the secondary piston (44) displaces a secondary volume of fuel into common rail (18) that is larger said primary volume.

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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

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FLOW INTENSIFIER FOR COLD STARTING GASOLINE DIRECT INJECTION ENGINE

Background of the Invention

The present invention relates to fuel injection systems for vehicle engines, and more particularly to common rail gasoline direct injection systems.

The design of the high pressure fuel pump for such common rail direct injection systems requires a number of trade-offs. For example, whereas the maximum required fuel delivery rate while the vehicle is under way can readily be accomplished with a modestly sized pump, the demands for a cold engine start require a delivery rate on the order of three times higher than the maximum needed for travel. As a consequence, conventional pumps are considerably oversized relative to the fuel delivery demands experienced during over 95 per cent of the engine operating time.

Summary of the Invention

Recognizing that the very high fuel delivery rate is needed for only a short period (a few seconds) during even the most severe cold start condition, the present inventor has solved this design problem not by oversizing the pump, but rather by incorporating an inline flow volume intensifier into the system. The intensifier can be either a stand-alone unit or it can be incorporated into the pump or into the rail.

Preferably the intensifier has a cranking configuration in which a primary piston of relatively low effective cross sectional area on which only the primary pressure of the pumping chamber is imposed, and a secondary piston contacting the primary piston and having a relatively large effective cross sectional area on which only the common rail pressure is imposed, whereby when the primary piston is displaced a primary volume toward the secondary piston by the primary pressure from the pumping chamber, the secondary piston displaces a secondary volume of fuel into the common rail that is larger said primary volume. The intensifier transitions .from the cranking configuration to a normal operating configuration when the secondary piston has been displaced to a limit position.

In the normal operating condition, a fluid connection of the high pressure fuel in the pumping chamber is effectuated with the fuel in the common rail

Brief Description of the Drawings

Figure 1 is a schematic of a portion of a common rail fuel injection system, with the flow volume intensifier according the invention, situated in series with the high pressure pump, in the high pressure line to the common rail;

Figure 2 and 3 show one hardware implementation of the intensifier unit according to invention; and

Figures 4-7 show the intensifier unit in various phases of operation.

Description of the Preferred Embodiment

Figure 1 is a schematic of a portion 10 of a gasoline common rail direct injection system, having a low pressure fuel feed line 12 delivering fuel to a high pressure pump 14. While the vehicle is underway during normal operation, the high pressure pump 14 and fuel line l6 maintain a pressure of, e.g., 120 bar or more, in the common rail 18, to which a plurality of injectors 20 are fluidly connected for injecting fuel into respective engine cylinders according to a control system (not shown). According to the preferred embodiment to be discussed in greater detail below, a flow intensifier 22 is situated in series with the pump 16, in the high pressure line 16.

Known plunger type pumps such as indicated at 14 can generate 120 bar pressure in a very short time, even at low R-PM. As only about 50 bar is needed to start a cold engine, the 120 bar pressure of the pump can be reduced in the intensifier 22, in exchange for gaining an inversely higher flow volume to the rail 18.

Figures 2 and 3 show one possible implementation of this inventive concept. The intensifier unit 22 comprises a tubular housing 24 having an inlet cap 26 sealing one end and an outlet cap 28 sealing the other end. The inlet cap has an inwardly extending collar 30 forming a cylinder in which is disposed a primary piston 32. An inlet passage 34 extends through the cap 26, for fluid

communication between the line 16 from the high pressure pump 14 and the cylinder 30 and thus against one end face of the piston 32. Another passage 36 extends axially part way through the piston 32, and then extends radially to ports 38 spaced from the end face 40. The collar 30 preferably has an outer diameter that is well within the inner diameter of the housing 24, thereby defining an annular expansion chamber 42.

A secondary piston 44 has an end face 46 that abuts the end face 40 of the primary piston. This end face 46 is preferably formed with a nose or nipple, for reasons to be discussed below. The secondary piston 44 opens toward the end cap 28, thereby forming a seat for spring 48 and, with the surrounding portion of housing 24, defining an intensification chamber 50. A passage 28 through the end cap 52 fluidly connects the intensification chamber 50 with the fuel line 16 and common rail 18.

A check valve and associated spring 54, 56 are situated in conjunction with a passage 58 extending between the face 46 of the secondary piston 44 and the intensification chamber 50. The optional nose or nipple in face 46 provides an offset for clearance between the passage 58 and end face 40 of the primary piston.

Figures 4-7 show the intensifier unit 22 in various phases of operation. In these figures, the expansion chamber 42' and the nose on face 46 of the secondary piston are diminished. A thickened portion of the housing forms the cylinder for the primary piston
32.

Figure 4 shows the unit after the vehicle has been standing unused for almost two weeks, whereupon the system has depressurized and the pressure in lines 12 and 16 has reached atmospheric (0 bar). However, line 16 and all passages and chambers in the unit 22 are full of fuel. The springs 48 and 54 are rather weak, being merely sufficient to maintain the configuration shown in Figures 3 and 4.

In Figure 5, the pump has started and quickly establishes a pressure of 120 bar at the primary piston 32, thereby displacing the primary piston sufficiently (e.g., 1000MM3) to raise the rail pressure to, e.g., about 50 bar.

According to Figure 6, additional fuel quantity (e.g., 4900 nun3) is supplied to the rail at 50 bar by the secondary piston 44. The secondary piston travel displaces a higher volume of fuel at a lower pressure, thereby producing the desired flow intensification.

Figure 6 shows the secondary piston bottomed out at the end cap after completing the intensification process. The primary piston 32 has been displaced such that the ports 38 reach the edge 60 of the structure defining the cylinder, thereby exposing the ports to the expansion volume 42'. As the secondary piston advances between the positions shown in Figures 4 and 6, the pressure in the expansion chamber 42' quickly reduces, but as the port 38 reaches the cylinder edge, fuel rapidly enters the chamber 42' at a very high pressure differential. For this reason, a larger expansion volume 42 such as shown in Figure 3 is preferred, thereby reducing the pressure differential.

After the expansion chamber fills with fuel, the pressure at both ends of the unit equalize at 120 bar and the unit becomes transparent to the remainder of the system 10. Fuel flows through passages 34, 36, ports 38, chamber 42', through passage 58 against the weak check valve arrangement 54,56, into chamber 50 and out passage 52.

As shown in Figure 7, after the pump 14 is stopped, the inlet pressure in passage 34 reduces to 0 bar and the rail pressure returns some fuel back to the intensifier, resetting the pistons to the position shown in Figure 4. This also reduces the rail pressure, and therefor reduces the post-shutoff pressure buildup resulting from fuel expansion during heat soak.

During hot start the engine will start instantly on residual pressure present in the rail. As soon as the intensifier secondary piston bottoms out, full pumping pressure will be available for injection. This initial phase can extend well into the normal engine operation phase without any harm.

Claims

1. In a common rail gasoline fuel injection system having a high pressure fuel supply pump in which fuel is pressurized in a pumping chamber and delivered through a high pressure passage to the common rail, the improvement comprising a flow volume intensifier situated in the high pressure passage.

2. The system of claim 1, wherein the intensifier has a cranking configuration in which a primary piston of relatively low effective cross sectional area on which only the primary pressure of the pumping chamber is imposed, and a secondary piston contacting the primary piston and having a relatively large effective cross sectional area on which only the common rail pressure is imposed, whereby when the primary piston is displaced a primary volume toward the secondary piston by the primary pressure from the pumping chamber, the secondary piston displaces a secondary volume of fuel into the common rail that is larger said primary volume.

3. The system of claim 2, wherein the intensifier transitions from said cranking configuration to a normal operating configuration when the secondary piston has been displaced to a limit position, and means are effective in said normal operating condition for fluid connection of the high pressure fuel in the pumping chamber with the fuel in the common rail.

4. The system of claim 3, wherein the means for fluid connection comprise flow passages through the pistons, which fluidly connected only when the intensifier is in said normal operating configuration.

5. The system of claim 4, wherein the primary piston is a solid body having said flow passages extending axially from an end face opposite the secondary piston, then radially outward to a primary piston port, and the secondary piston has a solid face confronting the primary piston and an open,

hollow body extending toward said stop limit, with said passage extending through said solid face.

6. The system of claim 5, wherein a one-way valve is provided in said flow passages.

7. The system of claim 5, wherein the primary piston is displaceable within a collar having an edge spaced from the solid face of the secondary piston, such that as the secondary piston reaches said stop limit, the port on the primary piston passes said edge and fuel from the pumping chamber enters said space, and passes through the solid face of the secondary piston.

8. The system of claim 7, wherein a one way valve is provided in the passage through the solid face of the secondary piston.

9. The system of claim 1, wherein the intensifier has a cranking configuration of pistons in which a primary volume of fuel pumped into the intensifier at a high pressure acts on a primary piston such that a greater volume of residual fuel associated with a secondary piston is discharged from the intensifier to the common rail at a lower pressure, and a normal operating configuration in which all the fuel pumped into the intensifier at high pressure is discharged from the intensifier to the common rail at substantially the same pressure.

10. The system of claim 9, wherein the high pressure pump delivers high pressure fuel to the intensifier at a pumping pressure above 100 bar and during the cranking configuration the intensifier delivers fuel to the common rail at a pressure less than about one-half the pumping pressure.

11. The system of claim 9, wherein the high pressure pump delivers high pressure fuel to the intensifier at a pumping pressure above 120 bar and during

the cranking configuration the intensifier delivers fuel to the common rail at a pressure no greater than about 50 bar.

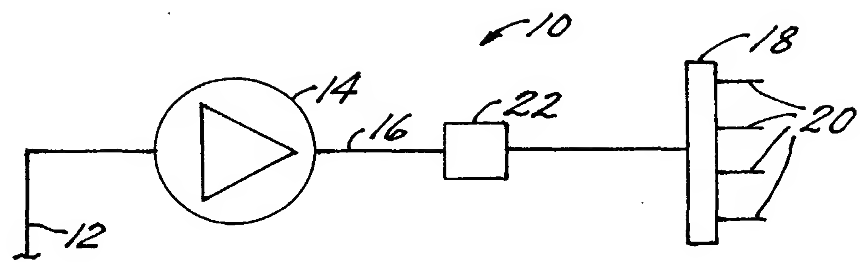

FIG. 1

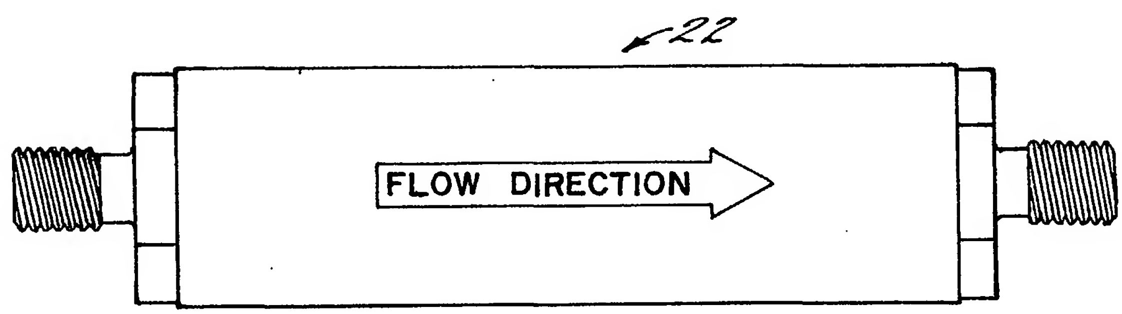

FIG. 2

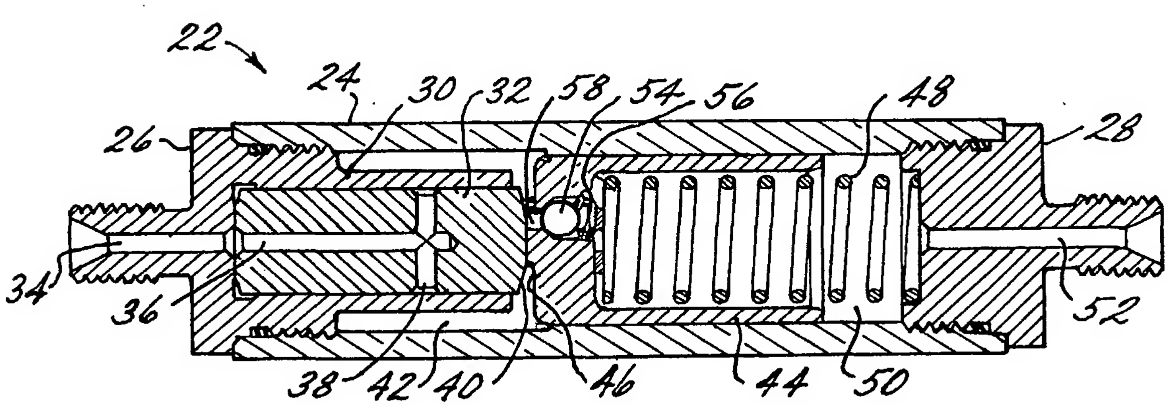

FIG. 3

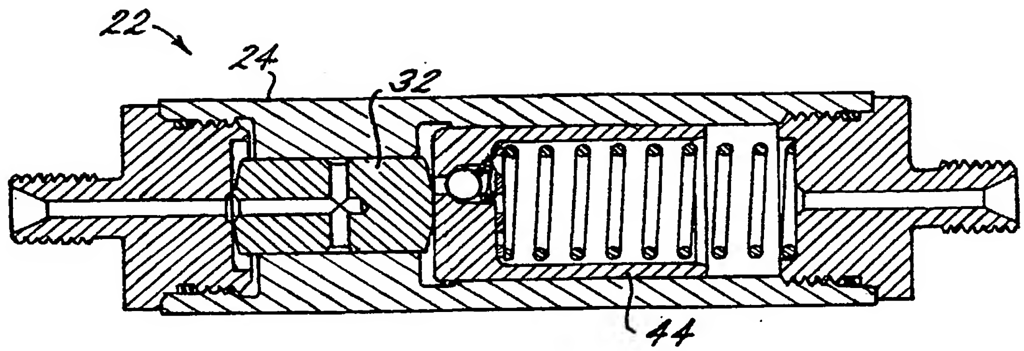

FIG. 4

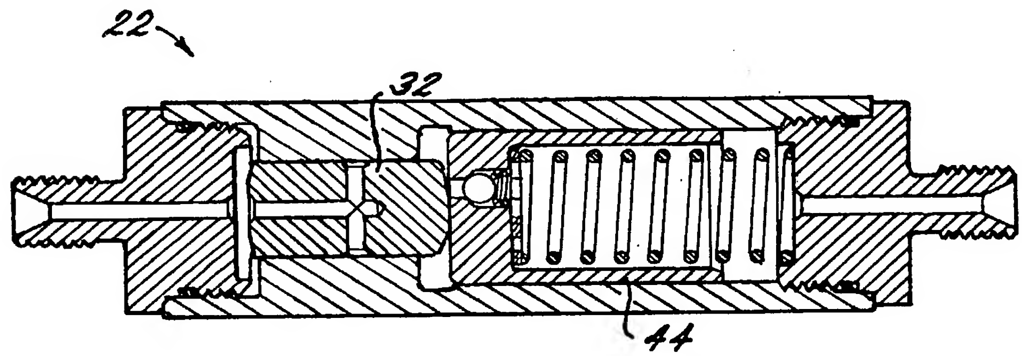

FIG. 5

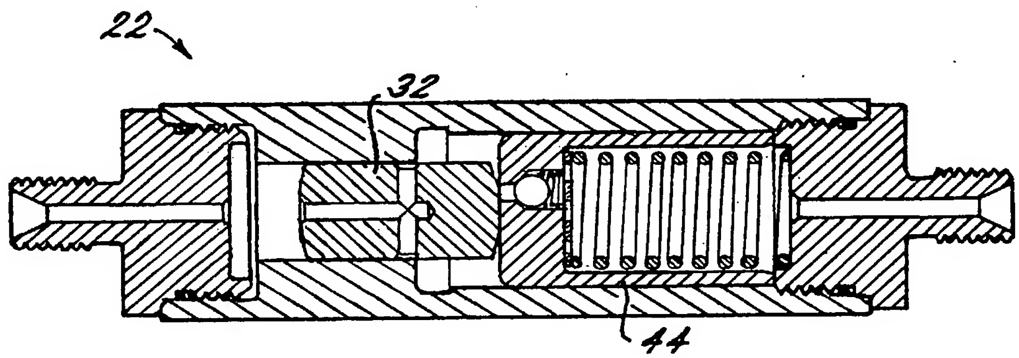

FIG. 6

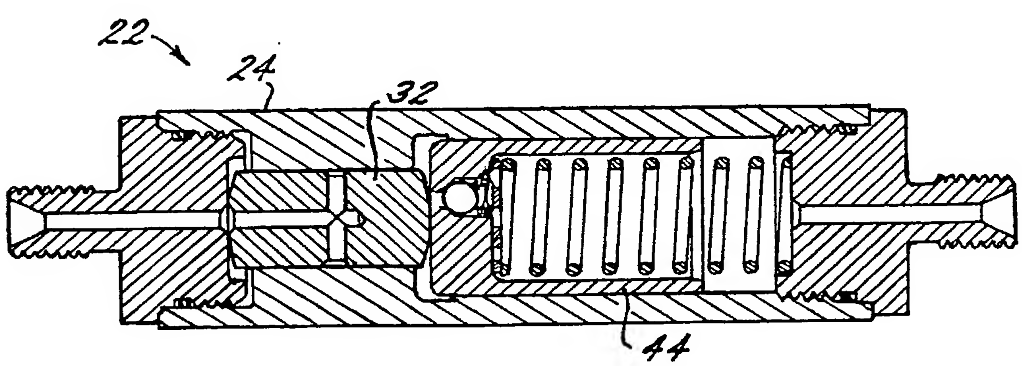

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/25214

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F02M63/02 F02M59/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 01, 30 January 1998 (1998-01-30) & JP 09 250426 A (TOYOTA MOTOR CORP), 22 September 1997 (1997-09-22) abstract ---	1
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 13, 5 February 2001 (2001-02-05) & JP 2000 297674 A (AISAN IND CO LTD), 24 October 2000 (2000-10-24) abstract ---	1
X	US 6 073 597 A (IMATAKE NOBUO ET AL) 13 June 2000 (2000-06-13) column 2, line 54 -column 3, line 58; figure 1 ---	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2002	29/01/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Torle, E

International Application No
PCT/US 01/25214

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 058 912 A (STUTZENBERGER HEINZ ET AL) 9 May 2000 (2000-05-09) column 6, line 46 -column 7, line 50; figure 1 -----	1

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/25214

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 09250426 A	22-09-1997	NONE	
JP 2000297674 A	24-10-2000	NONE	
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		JP 8319913 A	03-12-1996

DERWENT-ACC-NO: 2002-241959

DERWENT-WEEK: 200569

TITLE: Flow intensifier for use in cold starting common rail gasoline direct injection internal combustion engines

INVENTOR: DJORDJEVIC I

PATENT-ASSIGNEE: DJORDJEVIC I[DJORI] , STANADYNE AUTOMOTIVE CORP[STAW] , STANADYNE CORP[STAW]

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WO 0214685 A1	February 21, 2002	EN
AU 200184838 A	February 25, 2002	EN
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US 6899088 B2	May 31, 2005	EN
AU 2001284838 A8	September 15, 2005	EN

DESIGNATED-STATES: AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH CN CO CR CU CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ PL PT RO RU SD SE SG SI S K SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW AT BE CH CY DE DK EA ES FI FR GB GH GM GR IE IT KE LS LU MC MW MZ NL OA PT SD SE SL SZ TR TZ UG ZW

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WO2002014685A1	N/A	2001WO-US25214	August 13, 2001
AU 200184838A	N/A	2001AU-084838	August 13, 2001
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US20040011332A1	N/A	2003US-344837	July 10, 2003
US 6899088B2	Based on	2003US-344837	July 10, 2003

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CIPP	F02M37/00 20060101
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CIPS	F02M55/02 20060101
CIPS	F02M59/10 20060101
CIPS	F02M59/42 20060101
CIPS	F02M63/02 20060101

ABSTRACTED-PUB-NO: WO 0214685 A1

BASIC-ABSTRACT:

NOVELTY - A vehicle internal combustion engine has a common rail gasoline fuel injection system(10) supplied from a high-pressure fuel pump(14). The fuel is pressurised in a pumping chamber and delivered through a passage(16) to a common rail(18) and on to multiple fuel injectors(20). A flow volume intensifier (22) is located in the high-pressure passage(16) to deliver high volume flows for a short period during cold starting of the engine.

USE - As a flow intensifier for use in cold starting

common rail gasoline direct injection internal combustion engines.

ADVANTAGE - The flow intensifier reduces the maximum flow required from the high-pressure pump.

DESCRIPTION OF DRAWING(S) - The drawing shows a schematic of the fuel supply system.

Fuel supply system (10)

Low pressure feed line (12)

High pressure pump (14)

High pressure passage (16)

Common rail (18)

Fuel injectors (20)

Flow volume intensifier (22)

TITLE-TERMS: FLOW INTENSIFY COLD START COMMON RAIL GASOLINE DIRECT INJECTION INTERNAL COMBUST ENGINE

DERWENT-CLASS: Q53

SECONDARY-ACC-NO:

Non-CPI Secondary Accession Numbers: 2002-186802